Assessing and Visualizing Incomparabilities by using an Outranking Method Supporting the Acquisition of Military Equipment

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ABSTRACT

An essential element in the use of outranking methods for ranking or selection problems arising in the acquisition process of military equipment is the interpretation of incomparabilities. We show how this was done in the PROMETHEE methods by the "GAIA" plane representation, which is implemented in the commercial software "DECISION LAB 2000".

We then discuss how the incomparability analysis can be fine-tuned, leading to a more detailed graphical representation. This was implemented in the "MCDMTool" developed at the Royal Military Academy in Brussels.

Finally we discuss the way to interpret the results of these assessments and visualizations, along with their relevance to the acquisition process of military equipment.

INTRODUCTION

In the SAS-080 (NATO SAS-080 Specialist Meeting – Brussels 22-23 October 2009) contribution on "Using an outranking method supporting the acquisition of military equipment" (SAS-080 14) we reminded that outranking methods for multicriteria decision aid belong typically to the so-called European School of Multicriteria Decision Making (MCDM), which came into existence with the stimulating work of B. Roy ([13],[14],[15],[16]). We will repeat here some of the points addressed in that paper. The outranking approach is based on a fundamental partial comparability axiom where incomparability is a key concept ([5], p.80). In contrast with this approach there is the so-called American School in which Th. Saaty plays an important role with his "Analytical Hierarchy Process" (AHP Method) in which there is no place for incomparabilities [17]. In the European School we think that incomparabilities between alternatives to be ranked or to be selected, are a natural aspect of any MCDM problem, in which criteria evaluating the performance of these alternatives are conflicting – meaning that for instance two different criteria can have inversed preferences between couples of the same alternatives. If this happens on a large set of couples of criteria, then we claim that neglecting these conflicts, is leading to decisions which are often far from the original data of the MCDM problem. Although the final objective in practice is to decide about a ranking or about a selection of a subset of the alternatives, we claim that the decision maker should be supported by methods which are warning about the presence of incomparabilities. We even claim that it should be possible to assess the importance (the intensity) of these incomparibilities in order to fully inform the decision maker about it, before the final decision is made.

Many different methods belong to the outranking class. For overviews we refer to [5], [18] and [19]. For a detailed description of industrial applications with the oldest member (ELECTRE) of this class we refer to [11]. In this paper we will concentrate on the well-known PROMETHEE methods. In other contributions

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An essential element in the use of outranking methods for ranking or selection problems arising in the acquisition process of military equipment is the interpretation of incomparabilities. We show how this was done in the PROMETHEE methods by the GAIA plane representation, which is implemented in the commercial software DECISION LAB 2000. We then discuss how the incomparability analysis can be fine-tuned, leading to a more detailed graphical representation. This was implemented in the MCDMTool developed at the Royal Military Academy in Brussels.

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to the NATO SAS-080 Specialist Meeting (Brussels, 22-23 October 2009) we will focus on the ORESTE method ([10],[12]) which is complementary to the PROMETHEE methods. There are other methods belonging to the European School like MACBETH [1] which in SAS-080 is the subject of a keynote address by C. Bana e Costa.

The PROMETHEE methods are sufficiently well-known by System Analysis specialists, to skip in this paper all mathematical aspects. For details we refer to [4],[8] and [9]; for some more philosophical considerations see [3].

The PROMETHEE methods have been extensively used in the eighties and nineties of last century by teams of Belgian MoD equipment acquisition services. These (and other) MCDM methods are taught in the curriculum of the High Staff College for Military Administrators of the Belgian MoD. Currently personnel involved with equipment acquisition can use these methods on an individual basis. For other areas in Defence where these methods were used, we refer for instance to [6].

In this paper we concentrate on practical features of the PROMETHEE I method related to the incomparability analysis, the typical use for military equipment acquisition, and we illustrate the discussion primarily by an implementation we called MCDMTool [7].

INPUT DATA

We start with the same data as in the paper SAS-080 on “Using an outranking method supporting the acquisition of military equipment”, but now we intend to apply the PROMETHEE I method, which includes the identification of incomparabilities.

This is illustrated in Figure 1 with MCDMTool.

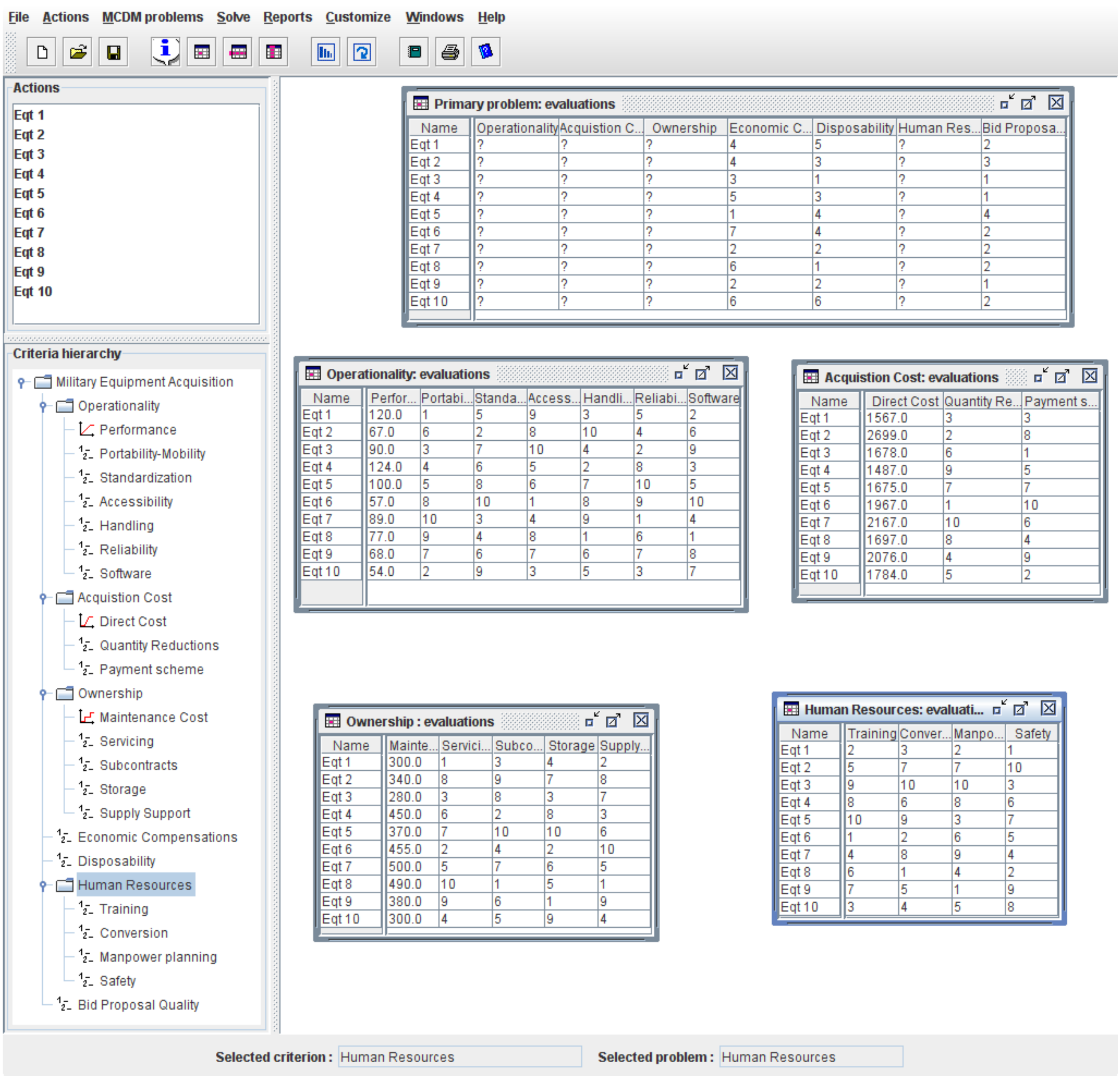

Figure 1: Input data in MCDMTool

PROMETHEE I COMPUTATIONS FOR OPERATIONALITY

In Figure 2 are shown the successive computational results for PROMETHEE I only for the MCDM-problem “Operationality” which is a criterion of the overall MCDM problem “Military Equipment Acquisition”. Notice that ordinal data (ranks are treated as cardinal data).

The second table of Figure 2 gives the unicriterion flows

$$\phi_j(a) = \sum_{x \in A-a} \left[P_j(a,x) - P_j(x,a) \right] \text{ with } P_j(a,x) \text{ and } P_j(x,a) \text{ the preference indicators}$$

(see SAS-080 14). They are used in the computation of weight stability intervals and also in the representation of the GAIA plane [9].

Operatio.. : PROMETHEE 1

Numerical evaluations | Unicriteria flows | Flows | PROMETHEE 1 relations

	Performance	Portability-Mobil...	Standardization	Accessibility	Handling	Reliability	Software
Eqt 1	120.0	1.0	4.0	9.0	3.0	5.0	2.0
Eqt 2	67.0	6.0	1.0	7.5	10.0	4.0	6.0
Eqt 3	90.0	3.0	7.0	10.0	4.0	2.0	9.0
Eqt 4	124.0	4.0	5.5	4.0	2.0	8.0	3.0
Eqt 5	100.0	5.0	8.0	5.0	7.0	10.0	5.0
Eqt 6	57.0	8.0	10.0	1.0	8.0	9.0	10.0
Eqt 7	89.0	10.0	2.0	3.0	9.0	1.0	4.0
Eqt 8	77.0	9.0	3.0	7.5	1.0	6.0	1.0
Eqt 9	68.0	7.0	5.5	6.0	6.0	7.0	8.0
Eqt 10	54.0	2.0	9.0	2.0	5.0	3.0	7.0

Operatio.. : PROMETHEE 1

Numerical evaluations | Unicriteria flows | Flows | PROMETHEE 1 relations

	Performance	Portability-Mobil...	Standardization	Accessibility	Handling	Reliability	Software
Eqt 1	0.7694444060...	1.0	0.3333333432...	-0.7777777910...	0.5555555820...	0.1111111342...	0.7777777910...
Eqt 2	-0.405555546...	-0.1111111342...	1.0	-0.4444444775...	-1.0	0.3333333432...	-0.111111134...
Eqt 3	0.1500000059...	0.5555555820...	-0.333333343...	-1.0	0.3333333432...	0.7777777910...	-0.777777791...
Eqt 4	0.8250000476...	0.3333333432...	0.0	0.3333333432...	0.7777777910...	-0.5555555820...	0.5555555820...
Eqt 5	0.4027777612...	0.1111111342...	-0.555555582...	0.1111111342...	-0.333333343...	-1.0	0.1111111342...
Eqt 6	-0.619444489...	-0.5555555820...	-1.0	1.0	-0.555555582...	-0.7777777910...	-1.0
Eqt 7	0.1222222149...	-1.0	0.7777777910...	0.5555555820...	-0.777777791...	1.0	0.3333333432...
Eqt 8	-0.183333352...	-0.7777777910...	0.5555555820...	-0.4444444775...	1.0	-0.1111111342...	1.0
Eqt 9	-0.383333325...	-0.3333333432...	0.0	-0.1111111342...	-0.111111134...	-0.3333333432...	-0.555555582...
Eqt 10	-0.677777767...	0.7777777910...	-0.777777791...	0.7777777910...	0.1111111342...	0.5555555820...	-0.333333343...

Operatio.. : PROMETHEE 1

Numerical evaluations | Unicriteria flows | Flows | PROMETHEE 1 relations

Phi +	Phi -	Phi total	Name	E01	E02	E03	E04	E05	E06	E07	E08	E09	E10
0.707...	0.254...	0.453...	Eqt 1	0.0	0.5454...	0.7727...	0.6363...	0.8181...	0.9090...	0.5045...	0.5454...	0.9090...	0.7272...
0.456...	0.448...	0.007...	Eqt 2	0.4545...	0.0	0.3636...	0.3636...	0.3636...	0.6818...	0.3636...	0.5454...	0.6363...	0.3318...
0.498...	0.421...	0.077...	Eqt 3	0.1818...	0.5590...	0.0	0.3636...	0.6363...	0.8772...	0.2772...	0.4227...	0.5545...	0.6181...
0.604...	0.343...	0.261...	Eqt 4	0.2	0.6363...	0.6090...	0.0	0.9272...	0.9090...	0.5227...	0.4545...	0.6363...	0.5454...
0.368...	0.567...	-0.19...	Eqt 5	0.0909...	0.6045...	0.2272...	0.0	0.0	0.7272...	0.3227...	0.3772...	0.5090...	0.4545...
0.173...	0.760...	-0.58...	Eqt 6	0.0909...	0.1818...	0.0909...	0.0909...	0.2727...	0.0	0.3636...	0.2727...	0.0909...	0.1045...
0.546...	0.372...	0.173...	Eqt 7	0.4545...	0.5545...	0.5454...	0.4545...	0.5454...	0.6	0.0	0.5090...	0.6409...	0.6136...
0.475...	0.428...	0.047...	Eqt 8	0.4545...	0.2272...	0.4545...	0.5454...	0.5454...	0.6363...	0.3636...	0.0	0.5863...	0.4681...
0.316...	0.577...	-0.26...	Eqt 9	0.0909...	0.1863...	0.3636...	0.1818...	0.4545...	0.7772...	0.2727...	0.2727...	0.0	0.2454...
0.484...	0.456...	0.028...	Eqt 10	0.2727...	0.5454...	0.3636...	0.4545...	0.5454...	0.7272...	0.3636...	0.4545...	0.6363...	0.0

Operatio.. : PROMETHEE 1

Numerical evaluations | Unicriteria flows | Flows | PROMETHEE 1 relations

	Eqt 1	Eqt 2	Eqt 3	Eqt 4	Eqt 5	Eqt 6	Eqt 7	Eqt 8	Eqt 9	Eqt 10
Eqt 1	I	>	>	>	>	>	>	>	>	>
Eqt 2	<	I	<	<	>	>	<	<	>	R
Eqt 3	<	>	I	<	>	>	<	>	>	>
Eqt 4	<	>	>	I	>	>	>	>	>	>
Eqt 5	<	<	<	<	I	>	<	<	>	<
Eqt 6	<	<	<	<	<	I	<	<	<	<
Eqt 7	<	>	>	<	>	>	I	>	>	>
Eqt 8	<	>	<	<	>	>	<	I	>	R
Eqt 9	<	<	<	<	<	>	<	<	I	<
Eqt 10	<	R	<	<	>	>	<	R	>	I

Figure 2: PROMETHEE I Computations

The third table of Figure 2 gives all the flows $\phi(a)$, $\phi^{+}(a)$ and $\phi^{-}(a)$ (see SAS-080 14), as well as all the aggregated preference indicators $\pi(a,b)$ and $\pi(b,a)$.

Finally the last table of Figure 2 gives the binary relations PROMETHEE I is obtaining for each couple of alternatives. Therefore the alternatives are ranked in decreasing order of $\phi^{+}(a)$ and in increasing order of $\phi^{-}(a)$. If for a couple of alternatives both rankings are the same, PROMETHEE I is maintaining this ranking as the final one. If for a couple of alternatives both rankings are opposite, then PROMETHEE I is

considering this couple as incomparable. In the last table of Figure 2 such couples are identified with the symbol *R*. There is no measure of the intensity of this incomparability in the original version of PROMETHEE I. This has been changed in the implementation of MCDMTool where we use de aggregated preference indicators $\pi(a,b)$ and $\pi(b,a)$ to represent each couple of alternatives in a IPR-diagram identical to the one we use for conflict analysis in the ORESTE method [10] (see SAS-080 16) with the same parameter settings to define the (blue) Indifference region (I), the (green) Preference region (P) and the (red) incompaRability region (R).

This is illustrated in Figure 3 with MCDMTool, along with the representation of the profiles of all alternatives. Notice that the couple of alternatives Eqt8 and Eqt10 are identified by PROMETHEE I as incomparable. This couple had the number 44 in the IPR-diagram ; it is in the middle of the incomparability region. The intensity of the incomparability can be measured by the distance of the point of the couple in the IPR-diagram, to the bisector of the first quadrant of this graph (see similarly [10]).

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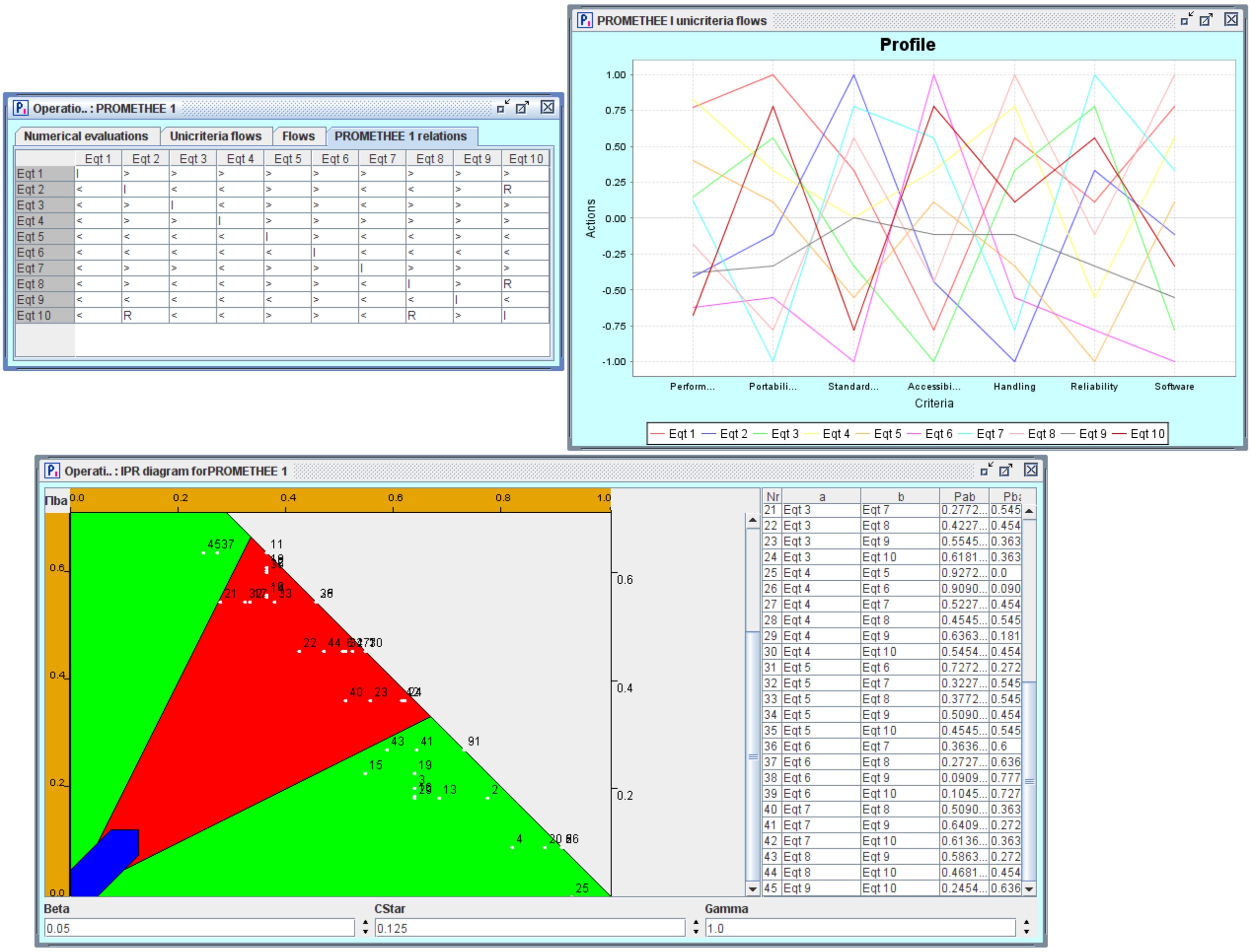

Figure 3: Conflict analysis for Operationality

INCOMPARABILITY ANALYSIS FOR THE MCDM PROBLEM

Finally the same is done for the overall MCDM problem. The results are illustrated with MCDMTool in Figure 4.

Notice that the couple Eqt7 and Eqt9 is not identified in the original version of PROMETHEE I as incomparable (see the upper left table in Figure 4), but it is in the IPR-diagram (see point 41 for this couple) because it is almost on the bisector of the (red) incomparability region. The original PROMETHEE I method is obviously not very discriminating for identifying incomparabilities.

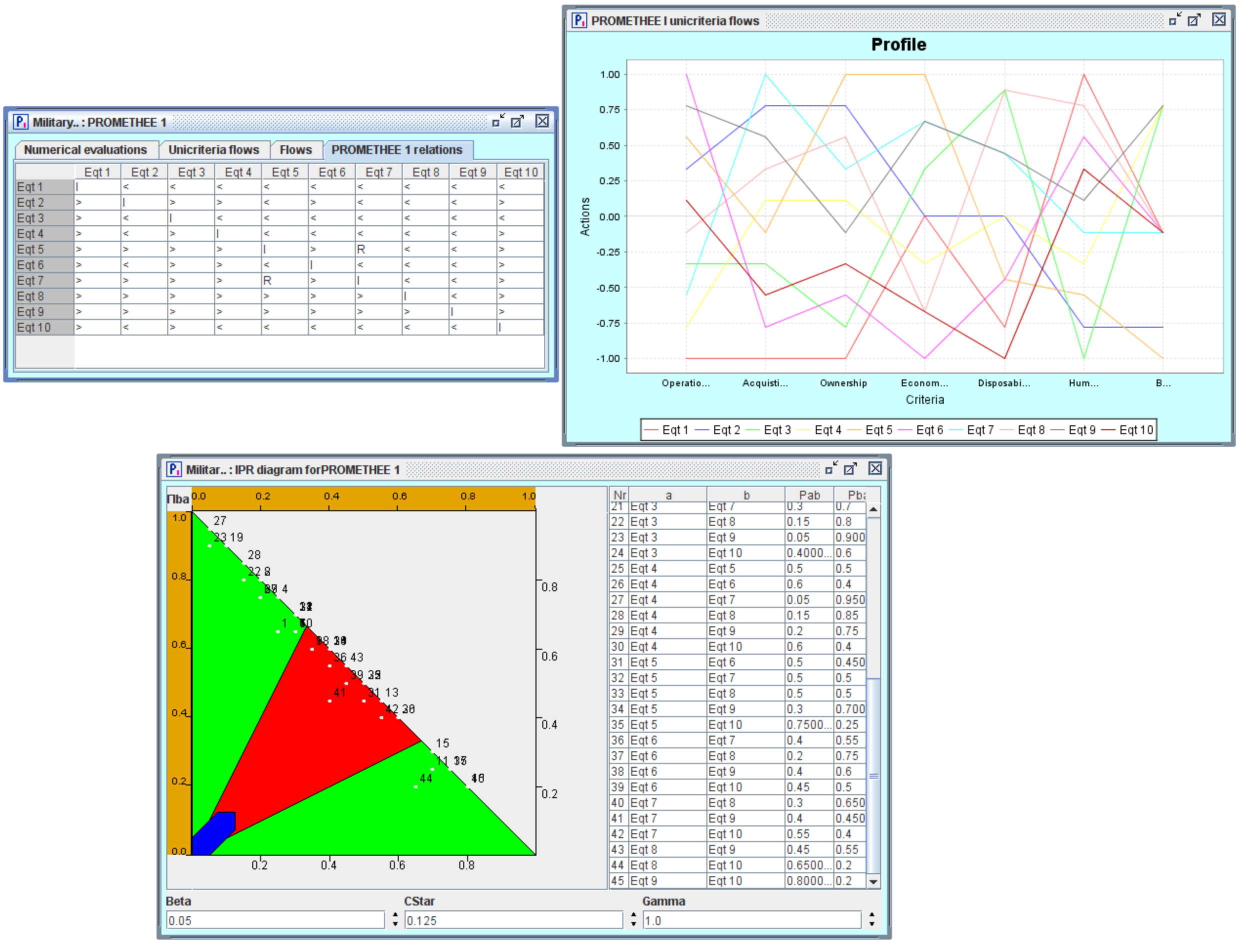

Figure 4: Final PROMETHEE I conflict analysis

CONCLUSION

In addition to the GAIA representation implemented in Decision Lab 2000 [20] the IPR-diagram implemented in MCDMTool is very important to assess the existence and the intensity of incomparabilities. This IPR-diagram is much more discriminating than the original version of PROMETHEE I.

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